# Do Local Manufacturing Firms Benefit from Transactional Linkages with Multinational Enterprises in China?

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## Abstract

This paper examines the linkage effects of foreign direct investment (FDI) on firm-level productivity in Chinese manufacturing. It is found that FDI generates positive vertical linkage effects in Chinese manufacturing at both the national and regional level, and limited positive horizontal spillovers at the regional level. While OECD firms gain from both vertical and probably horizontal linkages, Hong Kong, Macao and Taiwanese firms only benefit from backward linkage effects. In the domestic sector in which we are most interested, both SOEs and non-SOEs are hurt by competition from foreign firms in the same industries. While SOEs gain from vertical linkages with foreign firms, non-SOEs are unable to do so. The patterns of productivity spillovers from FDI in Chinese manufacturing seem to be determined by one key factor – technological capabilities of firms involved. Important data limitations and policy implications of this research are discussed.



JEL Codes: F2, O1, O3.

Key Words: FDI, Horizontal and vertical linkages, Firm and sector groupings; Technological capabilities.

## I. Introduction

Although the important role of foreign direct investment (FDI) in economic development in host countries is widely recognized, there have only been a few studies on linkage effects of foreign firms. On one hand, Rodríguez-Clare (1996), Markusen and Venables (1999) and Lin and Saggi (2005) present their respective theoretical models for the relationship between FDI, linkage and economic development. On the other, empirical analysis based on large firm-level data sets tends to focus on one dimension of linkage effects, i.e. horizontal linkages. To the best of our knowledge, only a few studies investigate both horizontal and vertical linkage effects simultaneously, including Driffield et al. (2002), Javorcik (2004) and Blalock and Gertler (2007) which offer empirical evidence of FDI linkage effects for the UK, Lithuania and Indonesia respectively.

While these studies shed some light on the channels through which a local economy may benefit from the presence of FDI, there is still "a significant gap between the consensus among practitioners and the empirical literature regarding the importance of positive FDI externalities" (Alfaro and Rodríguez-Clare, 2004). Given that a key factor determining the benefits host countries can derive from FDI is the linkages that foreign affiliates establish with indigenous firms (UNCTAD, 2001), "certainly more research is needed to fully understand the effect of FDI on host countries" (Javorcik, 2004).

This paper aims to add to the analysis of FDI linkage effects in a large emerging economy – China. Specifically, it adopts a two-step procedure similar to that employed by Javorcik (2004) to examine the extent to which the presence of FDI impacts on firm-level productivity in Chinese manufacturing. In the first step, total factor productivity (TFP) in firms is estimated using the Levinsohn-Petrin (2003) method. Then the linkage effects of FDI on TFP are investigated. An application of different measures of foreign presence to catch possibly different aspects of the linkage effects at both the national and regional levels and on firms of different ownership is a feature of this study. We find positive vertical linkage effects in Chinese manufacturing at the national and regional level, and limited positive horizontal spillovers at the regional level. FDI linkage effects vary with firms of different ownership and to some extent with different measures of foreign presence. While OECD firms gain from both vertical and probably horizontal linkages, Hong Kong, Macao and Taiwanese firms only benefit from backward linkage effects. In the domestic sector in which we are most interested, both state-owned enterprises (SOEs) and non-SOEs are hurt by competition from foreign firms in the same industries. While SOEs gain from vertical linkages with foreign firms, non-SOEs are unable to do so.

The remainder of the paper is structured as follows. Section II reviews the relevant literature and provides our arguments. Section III describes our empirical model, data and methodology. Section IV presents estimation results. Finally, section V summarizes the main findings and discusses policy implications as well as limitations of the study.

## II. Literature Review

FDI is a package of capital, technology and managerial skills, and is viewed as an important source of both direct capital inputs and indirect knowledge spillovers (Balasubramanyam et al. 1996). As widely accepted, the most important reason why many countries are determined to attract FDI is the prospect of acquiring modern technology. Broadly interpreted, technology includes product, process, and distribution technology, as well as management and marketing skills (Blomström and Kokko, 1998).

It is now widely recognized that the strongest channel for diffusing skills, knowledge and technology from foreign affiliates is the linkages they establish with local firms and institutions. Such linkages can contribute to the growth of a vibrant domestic sector, the bedrock of economic development (UNCTAD, 2001). It is also widely acknowledged that the mechanisms of knowledge spillovers via horizontal linkages are different from vertical linkages (Blomström and Kokko, 1998; Aitken and Harrison, 1999; Javorcik, 2004).

### II.1 Horizontal Linkages

As defined in UNCTAD (2001), horizontal linkages involve interactions with firms engaged in competing activities. In this process, spillovers may take place when local firms improve their efficiency by copying technologies of multinational enterprises (MNEs) either through observation or by hiring workers trained by the MNEs, and when local firms are forced to use their resources more efficiently or search for new technologies because of severe competition from MNEs. However, these channels may rarely work effectively. If local and foreign firms compete in the same industry, then the latter have an incentive to prevent technology leakage and spillovers from taking place by protecting their intellectual property, trade secrecy, paying higher wages to prevent labor turnover, or locating in countries or industries where local firms have limited imitative capacities to begin with.

Perez (1997) maintains that the capacity of firms to 'catch up' depends on their level of competitiveness. The extent to which competing firms can benefit from horizontal linkages of FDI also depends on the technology gap between these firms and MNEs: (1) if competing firms do not lag too far behind MNEs they can embark on a catch-up process and benefit from the presence of FDI; (2) if competing firms are far behind MNEs it may be impractical for them to benefit substantially from foreign firms' knowledge and consequently they fall even further behind (Cantwell, 1989, 1995). Furthermore, Aitken and Harrison (1999) note "market-stealing effects", i.e. the entry of local-market-oriented foreign firms can draw demand from local firms, causing them to cut production. Thus, the productivity of local firms would fall as they are forced back up their average cost curves. As a result, net productivity can decline. Thus, productivity spillovers can be negative as well as positive. In a recent survey, Görg and Greenaway (2004) find only twenty two out of the forty selected studies of horizontal productivity spillovers (up to the year of 2002) report unambiguously positive and statistically significant externalities.

There are several studies on FDI horizontal spillovers in China using firm-level panel data, including Hu and Jefferson (2002), Wei and Liu (2006) and Wei et al. (2008). Hu and Jefferson (2002) confirm the existence of negative horizontal spillover effects of FDI in the electronics industry, but not in the textile industry, while Wei and Liu (2006) and Wei et al. (2008) report positive horizontal spillovers of FDI in Chinese manufacturing. Wei and Liu (2006) suggest that the spillover effects may depend partially on the way foreign presence is measured because each of the indicators identified in the literature (equity capital, employment, R&D, exports, sales and output) may capture a different aspect of spillover effects. Would the conclusion of little positive horizontal spillovers in developing countries be altered if different measures of foreign presence are utilized in the linkage effect research? This is one of the questions this research paper attempts to answer.

### II.2 Vertical Linkages

Vertical linkages include both backward linkages and forward linkages. Backward linkages exist when foreign firms acquire goods and services from firms in upstream industries. They can contribute to the upgrading of local firms and embed foreign firms more firmly in host economies (UNCTAD, 2001). Dunning (1993) shows that FDI may affect suppliers not just in terms of the quantities of goods and services that are purchased, but also through an impact on the quality of inputs, and the efficiency with which those inputs are supplied. Backward linkages from MNEs to local firms are important channels through which intangible and tangible assets can be passed on from the former to the latter. Javorcik (2004) argues that MNEs have no incentive to prevent technology diffusion to upstream sectors as they may benefit from improved performance of intermediate input suppliers. MNEs may directly transfer knowledge to their local suppliers, urge them to upgrade their production management and technology and allow them to reap economies of scale. Thus, positive productivity spillovers are expected from backward linkages. The econometric studies of Driffield et al. (2002), Javorcik (2004) and Blalock and Gertler (2007) all confirm the existence of positive backward linkages from FDI.

However, there are growing suspicions regarding the positive effects from backward linkages. In their theoretical model, Lin and Saggi (2005) argue that FDI can affect the degree of backward linkages in two conflicting ways. Firstly, it creates demand for intermediate products (demand effect). Secondly, local firms competing with foreign firms may be forced to reduce their output and hence their own demand for the intermediate products (competition effect). If the competition effect exceeds the demand effect, there will be net negative backward linkage effects. Dolan and Humphrey (2000), Weatherspoon and Reardon (2003) and Dries and Swinnen (2004) provide some anecdotal evidence that there are negative spillovers from backward linkages in developing countries as local suppliers cannot comply with the higher standards and grading requirements for the supplied products.

Forward linkages arise when foreign firms sell goods and services to local firms. This type of linkage may contribute to the development of local distribution and sales organizations (Reuber et al. 1973; Blomström and Kokko, 1998). Forward linkages may also facilitate the adoption of new technologies and can solve contract enforcement problems (Gow and Swinnen, 1998; Key and Runsten, 1999; Dries and Swinnen, 2004). There are few econometric studies on forward linkages, and there is much less evidence of forward than backward linkages. Nevertheless, Driffield et al. (2002) find some positive externalities in local firms who make purchases from the foreign sector in the UK.

In conclusion, theoretically, productivity spillover effects of horizontal and vertical linkages can be positive, negative or insignificant. Existing empirical studies based on large firm-level panel data largely focus on horizontal linkages and there is no conclusive finding on the spillover effects from horizontal linkages in developing countries. Only a few studies look at horizontal and vertical linkages simultaneously and conclude that vertical linkages are more likely to generate positive spillovers than horizontal ones.

## III. Data and Methodology

Our empirical analysis is based on data compiled by the State Statistical Bureau of China. The primary data are taken from the *Annual Report of Industrial Enterprise Statistics*, covering firms during the period of 1998-2001. Deflators employed are price indices for total manufacturing fixed assets and industrial output and are obtained from the *China Statistical Yearbook 2002*. To construct linkage variables, the *1997 Input-Output Table of China* is used. A more detailed description of the data sources and variable definitions is provided in Appendix A.

To estimate the impact of the linkage effects of foreign firms on local productivity, we adopt a two-step procedure similar to that employed by Javorcik (2004). First, we estimate firms' total factor productivity (TFP). In the second step, the linkage effects of FDI on TFP are investigated.

There are a number of alternative means of measuring TFP including index numbers, data envelopment analysis, stochastic frontier analysis, instrumental variables estimation techniques and semiparametric estimation techniques. Van Biesebroeck (2007) provides a detailed review and uses Monte Carlo simulations to evaluate the sensitivity of estimators to various complications. The semiparametric method developed by Olley and Pakes (1996) is shown to be remarkably robust to different forms of measurement and specification errors. Olley and Pakes (1996) proxy method is modified by Levinsohn and Petrin (2003). Both methods control for simultaneity bias and selection bias, but their main difference is the proxy used.

There are reasons to believe that firms adjust their inputs according to their expectations (Griliches and Mairesse, 1995), so input levels are most likely correlated with idiosyncratic shocks in productivity captured in the error term. Using least squares cannot produce consistent estimates. The principle of the proxy methods is to use another decision by the firm to provide separate information on the unobserved productivity term. In Olley and Pakes (1996), investment is assumed to be a monotonic function of productivity. But with this method, firms with zero investment are excluded from the sample. Levinsohn and Petrin (2003) propose to use intermediate inputs as a proxy. They highlight three advantages of using intermediate inputs as compared with using investment. First, there is a stronger link between economic theory and estimation with intermediate inputs as a valid proxy. Second, intermediate inputs respond to the entire productivity term, whereas investments partially respond to the "news" in the unobserved term. Third, firms usually have positive intermediate inputs though often incur zero investment. A brief description of the Levinsohn-Petrin estimation procedure is provided in Appendix B.

After deriving TFP estimates from heterogeneous, industry-specific production functions, we then relate TFP to FDI variables. In this step, FDI is expected to have linkage effects on firm productivity.

$$\ln(TFP_{ijt}) = \alpha_0 + \alpha_1 HLFP_{jt} + \alpha_2 BLFP_{jt} + \alpha_3 FLFP_{jt} + \delta X + \mu_{ijt} \qquad (1)$$

where $\ln(TFP_{ijt})$ is the logarithm of the TFP of firm i in sector j at time t. HLFP, BLFP and FLFP capture the horizontal, backward and forward linkages of foreign firms respectively. X is a vector of control variables.

Given that our aim is to assess the extent of spillovers through horizontal and vertical linkages of foreign firms, we need some indices for foreign presence in these linkages. As indicated earlier, we propose that different measures may capture different aspects of productivity spillovers. If foreign equity capital is applied, then the positive spillover effects may indicate that the foreign presence produces positive capital spillover effects and vice versa. In this case, the externalities are closely related to the demonstration effect of the suitability of the project, or the superiority of machinery or equipment embodying updated technologies. Similarly, if employment in foreign firms is applied, then the spillover effects will be closely associated with employee turnover or contagion between employees in foreign and local firms. This can be referred to as employment spillovers. Following Aitken and Harrison (1999) and Javorcik (2004), we also use weighted foreign equity capital as measures. Consequently, we have the following four measures for intra-industry FDI spillover effects (i.e. horizontal linkage effects):

1. the share of foreign equity capital in the sector's total equity capital (CA);
2. the share of MNEs' employment in the sector's total employment (EM);
3. the share of foreign equity participation weighted by sales (SAW); and
4. the share of foreign equity participation weighted by employment (EMW).

Similar to Driffield et al. (2002), Javorcik (2004) and Blalock & Gertler (2007), in this paper the linkage variables are approximated by using weights derived from the input-output (I-O) table. The I-O table gives the share of goods in industry *m* used for the production of each unit of the goods in industry *n*. The underlying assumption is that the amount of knowledge gained from FDI in an industry *m* is proportional to industry *m*'s importance in industry *n*'s input or output structure and FDI share in industry *n*.

Backward linkage effects measure the extent to which firms in upstream industry *n* purchase inputs from firms in downstream industries. In the present context, backward linkage effects result from MNEs using intermediate inputs (including goods and services) purchased locally. FDI backward linkages are proxied by $\sum \alpha_{mn} HLFP_n \;\; m \neq n$, where $\alpha_{mn}$, obtained from the I-O table, is the proportion of industry *m*'s output supplied to industry *n*. $\mathrm{HLFP}_n$ is the foreign presence in industry *n* which measures intra-industry or horizontal linkage effects of FDI. To illustrate the meaning of the variable, we here provide an example. Our data show that the electricity transmission, distribution & control equipment sector (I-O code 75 in Table A1) sold 0.03% of its output to the computer sector (I-O code 76 in Table A1), 0.3% to the household electronic appliances sector (I-O code 77 in Table A1), 1.57% to the electronic devices and components sector (I-O code 78 in Table A1), and 0.21% to the other electronic and telecommunication equipment sector (I-O code 79 in Table A1). The shares of foreign output in these sectors were 85.75%, 75.19%, 79.35% and 80.94%, respectively, in 2000. The backward linkage variable measured by industrial output for these sectors should then be 0.0167 (=85.75%*0.03% + 75.19%*0.3% + 79.35%*1.57% + 80.94%*0.21%), implying that approximately 1.67% of output in the electricity transmission, distribution & control equipment sector was sold to foreign firms in the electronic and telecommunication equipment sector.

Analogously, forward linkage effects measure the extent to which firms from upstream industry *m* sell their outputs to firms in downstream industries. Forward linkage effects result from foreign firms supplying intermediate inputs to downstream industries. It is proxied by $\sum \beta_{mn} HLFPD_n \;\; m \neq n$, where $\beta_{mn}$ is the share of inputs purchased by industry *m* in total inputs provided by industry *n*. $HLFPD_n$ is the share of MNEs' assets/employment/sales in industry *n* which are present locally. HLFPD equals HLFP for all other cases except for sales which should be sales minus exports (DSW). This is straightforward as only goods and services provided locally by foreign firms create any forward linkage. Exported goods and services by foreign firms are not expected to have the impact they might have on the domestic market.

Table 1 provides a breakdown of the share of foreign sector by individual manufacturing sectors. Shares of foreign firms in total number of firms in our panels range from 23% in beverage production to 79% in garment production. The table reveals that there is a greater concentration of foreign firms in labor intensive, low and medium-tech sectors[i].

<Table 1 about here>

Before proceeding to the empirical results, we need to address a few econometric concerns. Firstly, the correlation between foreign presence and productivity enhancement in firms may be affected by other factors such as fixed firm-, time-, industry- and region-specific factors such as high-quality management, infrastructure and technology opportunity. To control for these fixed effects, we include firm-, year-, industry- and region-dummies, wherever appropriate. An alternative method to the fixed effects model is differencing (Wooldridge, 2002). The choice between first differencing and fixed effects hinges on the assumption about the idiosyncratic errors. In particular, the fixed effects estimator is more efficient if the idiosyncratic errors are serially uncorrelated, while the first differencing estimator is more efficient when the idiosyncratic errors follow a random walk (Wooldridge, 2002). However, partly because our panel data structure has a short time period (only four years), our discussion will be based mainly on the fixed effects models, but the results of first differencing models will also be briefly compared and discussed.

Secondly, since our linkage measures vary across industries, any clustering in the residuals $\mu_{ijt}$ in (1) may be exacerbated (Moulton, 1990). Hence equation (1) is estimated with correction for heteroskedasticity and for clustering at the industry-year level. In other words, in all estimations, we allow for clustering at the industry-year level to account for correlations between firm observations within the same industry-year. According to Wooldridge (2002, pp. 275-276), "the robust variance matrix estimator is valid in the presence of any heteroskedasticity or serial correlation in the idiosyncratic errors $\{u_{it}: t = 1, \ldots T\}$, provided that T is small relative to N". Our dataset covers 4 years and around 30,000 firms, so serial correlation is more likely to be within the group. This clustering method using the robust variance matrix is a valid approach to addressing serial correlation. We have followed Wooldridge (2002) to scale the standard errors to take into account alternative forms of serial correlation and heteroskedasticity, that is, to allow correlated errors within the cluster.

The final econometric issue is selection bias which may occur due to firm entry and exit, but which may also simply reflect some firms choosing not to report. This problem can, to some extent, be controlled for by the use of unbalanced panels (Levinsohn and Petrin, 2003). Alternatively, it can be dealt with using the Heckman (1979) technique. However, Levinsohn and Petrin (1999) demonstrate that controlling for selection bias has little effect on the final parameter estimates. Furthermore, as argued by Haskel et al. (2007), "research is ongoing as to the best estimator for addressing issues such as selection". Following Haskel et al. (2007), we too decide not to implement a structural approach to address selection bias.

## IV. Empirical Results

The summary statistics of the variables including means and standard deviations are provided in Table 2. Standard deviations for between and within components suggest, for all variables under consideration, that variation across firms is greater than that within a firm over time[ii]. Different measures of horizontal, backward and forward linkages are highly, but not perfectly correlated, respectively[iii]. As a result, each of the four measures of the spillover variables enters equation (1) separately in order to avoid multicollinearity.

<Table 2 about here>

Different estimation methods produce different coefficients on labor and capital. The results for returns on capital and labor using ordinary least square (OLS), fixed effects (FE) and Levinsohn-Petrin (LP) estimation methods are given in Table 3[iv]. As OLS does not take into account the unobserved firm characteristics, such as management, infrastructure and the availability of finance that could affect firm's productivity, we follow Haskel et al. (2007) and estimate production functions using a FE model incorporating a full set of firm, industry, year and regional fixed effects. However, there are still problems of a simultaneity bias and selection bias as discussed in the previous section. To address the problem, we employ the LP method. In addition, we also relax the assumption that the production function coefficients are the same for all industries by employing estimation techniques industry by industry. Table 3 reveals that, using all three methods, capital and labor elasticities are positive and statistically significant for all eight industries in the sample. However, because productivity shocks and input usage tend to be correlated, the OLS coefficients are likely to be biased, which is confirmed in Table 3.

<Table 3 about here>

### IV.1 Linkage Effects on All Firms

We start with estimating equation (1) for all firms, whether they are foreign or local, in Chinese manufacturing. In Table 4, the results of linkage effects of FDI on firm productivity are presented. In these estimations, the dependent variable is the logarithm of TFP which is recovered from the LP method. The independent variables in which we are particularly interested are horizontal, backward and forward linkages from FDI. The equation also includes firm, industry, year and region dummies. The model goodness-of-fit test statistics are all statistically significant.

<Table 4 about here>

As can be seen from Table 4, the coefficients on all four alternative measures of horizontal spillover variable are statistically insignificant. This seems to indicate that the productivity of firms is not significantly influenced by foreign firms in the same industry. The results on the vertical linkage variables are very encouraging. The coefficients on all the four different measures of backward linkages are consistently positive, and statistically significant. Very similar results can be identified for forward linkages. The effect of vertical linkage variables on productivity seems to suggest an economically meaningful relationship. For example, *ceteris paribus*, a one-standard-deviation increase in the backward linkage variable measured by capital (14.5%), on average, results in a rise of 23% TFP growth and a one-standard-deviation increase in the forward linkage variable measured by capital (5.2%), on average leads to an 8.3% increase in TFP growth. Hence, our findings tend to suggest that FDI has generated positive productivity spillovers via vertical linkages, i.e. both backward and forward linkages. The vertical linkage effects may come from demonstration effects, labor contagion effects, or the combination of the two.

### IV.2 Linkage Effects at the Regional Level

Spillover effects could be received first by the neighboring firms. The benefits may then gradually spread to other, more distant firms. Are the spillover effects in China local or national in scale? Following Aitken and Harrison (1999), we include both regional and sectoral variables in the same regressions. All firms are grouped into 29 regions which are defined at the level of province, autonomous region and central municipality[v]. The results for the linkage effects at the regional level are reported in Table 5.

<Table 5 about here>

It can be seen that, among the four within-the-region horizontal variables only equity capital weighted by employment is statistically significant. Furthermore, among the four within-the-region backward linkage variables, only equity capital and equity capital weighted by employment are statistically significant. On the other hand, three out of the four within-the-region forward linkage variables remain statistically significant. These results indicate that there is some (weak) evidence of both positive horizontal and positive vertical spillover effects from FDI within regions. In horizontal linkages, productivity spillovers tend to occur only when the demonstration and contagion effects work together. In vertical linkages, the demonstration and contagion effects work either independently or jointly. The regression results indicate that the examination of spillover effects is indeed sensitive to the way foreign presence is measured. If horizontal linkage was not measured by equity capital weighted by employment, any evidence of linkage effects would not be revealed.

### IV.3 Linkage Effects on Different Groups of Firms

So far we have found evidence of productivity spillovers via vertical linkages at the national and regional level and some (weak) evidence of productivity spillovers from horizontal linkages at the regional level. However, which group of firms benefits most from the presence of FDI, foreign or indigenous Chinese firms[vi]? Studies such as Aitken and Harrison (1999) find that horizontal spillovers from foreign firms mainly benefit other foreign firms, not domestically-owned firms in the same industry. To what extent is Venezuela's experience resembled by China?

In China, industry used to be dominated by state-owned enterprises (SOEs), but economic reform has resulted in a substantial change in ownership structure. According to the most recent China economic census (http://www.stats.gov.cn/zgjjpc/index.htm), the share of SOEs in terms of the registered number of enterprises had declined by 48% to 192,000 during the period of 2001 and 2004 and only accounts for 6% of the total 3,250,000 enterprises. On the other hand, the non-state-owned Chinese firms have gained momentum, especially privately-owned firms. There were 2,096,000 non-state-owned Chinese firms, among which 1,982,000 were privately-owned. Foreign firms also see their importance increase. In China's FDI statistics, there are two main types of foreign investors: overseas Chinese investors from Hong Kong, Macao and Taiwan (HMT), and other investors mainly from OECD countries. The number of HMT firms was 74,000, while that of OECD firms was 78,000, each accounting for over 2% of the total.

It is recognized that HMT and OECD firms have heterogeneous properties, pertaining to, e.g. size, labor productivity, profitability and technological capability. OECD firms are superior to HMT firms in product innovation and technological development (Huang, 2004; Wei and Liu, 2006). The productivity of a foreign firm is expected to be influenced by the presence of all other foreign firms in Chinese manufacturing. On the other hand, for domestic sectors, SOEs are still perceived as facing soft-budget constraints and privileged access to financial capital. Non-SOEs are much more market-oriented than SOEs. Indigenous Chinese firms of different ownership behave differently with respect to imitation, innovation and competition, and have different technological capabilities for knowledge absorption from the presence of foreign firms (Li et al. 2001). Huang (2004) notes that, in the scope of cooperative operations, HMT firms have a tendency to prefer to cooperate with non-SOEs, whereas OECD firms tend to prefer to cooperate with SOEs. This fact may also have significant implications for the spillover effects of FDI for different groups of firms.

This subsection compares the linkages effects of FDI on these four types of firms. The results are presented in Table 6. For HMT firms, there is no evidence of horizontal productivity spillovers from other foreign firms to HMT firms in Chinese manufacturing because not a single measure of horizontal linkages is statistically significant. There is no evidence of productivity spillovers from forward linkages either. However, the significantly positive coefficients on backward linkages measured by equity capital and equity capital weighted by sales offer some evidence of spillover effects on HMT firms due to their vertical linkages with all other foreign firms, whether they are HMT or OECD ones.

As for the group of OECD firms, the coefficients on the horizontal linkage variables measured by equity capital and equity capital weighted by sales are positive and statistically significant. All the coefficients on vertical linkages are positive and statistically significant except on forward linkages measured by equity capital weighted by sales. So, it seems that there is some evidence of productivity spillovers from foreign presence to both HMT and OECD firms in Chinese manufacturing. There also seems to be more evidence of vertical spillovers than horizontal ones. Comparing the two groups of foreign firms, OECD firms tend to benefit more from foreign presence than HMT firms do, as the former enjoy positive productivity externalities not only from backward linkages (as HMT firms do), but also from forward and some horizontal linkages with all other foreign firms. This result may not be a surprise. Since the technological and hence the absorptive capabilities of OECD firms are generally higher than those of HMT firms (Buckley et al, 2002; Wei and Liu, 2006), the former are able to learn more than the latter in their transactional linkages.

<Table 6 about here>

Turning to the domestic sector in which we are most interested, the level of productivity in SOEs is positively correlated with all different measures of backward and forward linkages. There is some evidence of negative productivity spillovers from FDI in the same industries, as the coefficients on horizontal linkages measured by employment and equity capital weighted by employment are negative and statistically significant. This suggests that the competition from foreign firms is so fierce that its negative impacts significantly outweigh foreign firms' possibly positive demonstration and contagion effects on SOEs in the same industries. However, this does not prevent SOEs from benefiting from vertical linkages with foreign firms as the latter may be more willing to transfer knowledge to their local suppliers or offering assistance to their local customers.

Finally, we examine the linkage effects on non-SOEs. Similar to the case of SOEs, there is evidence of negative horizontal spillovers as the coefficients on horizontal linkages measured by employment and equity capital weighted by employment are statistically significant. The insignificant coefficients on vertical linkage variables indicate that there is no significant relationship between the level of productivity in non-SOEs and foreign presence in different industries. Thus, non-SOEs do not perform as well as SOEs in terms of learning via vertical linkages with foreign firms. In horizontal linkages, like SOEs, non-SOEs are technologically disadvantaged compared with their foreign counterparts in Chinese manufacturing. The negative externalities non-SOEs suffer via competition from foreign firms may significantly exceed any possible positive gains arising from demonstration and contagion effects. In vertical linkages, probably because non-SOEs are relatively inexperienced and have smaller size and lower technological capabilities than SOEs, they are unable to benefit from their transactional linkages with MNEs in different industries. However, this result needs to be interpreted with caution. As our sample does not include those small-sized enterprises, it is likely that the obtained results underestimate the possible linkage effects of FDI on non-SOEs.

In summary, China's experience seems to resemble that in other emerging economies. Similar to Venezuela (see Aitken and Harrison, 1999), horizontal spillovers of FDI have been confined to a certain group of foreign firms, while domestically-owned firms are actually hurt by competition from foreign firms. Compared with the experience of Lithuania (see Javorcik, 2004) and Indonesia (see Blalock and Gertler, 2007), Chinese SOEs, like Lithuanian and Indonesian firms benefit from backward linkage effects.

However, different from Lithuanian firms, they also enjoy forward linkage effects[vii]. On the other hand, unlike local Lithuanian and Indonesian firms, Chinese non-SOEs not only face tough competition from foreign firms in the same industries, but they do not appear to significantly gain from any vertical linkages at all.

### IV.4 Alternative Estimation Methods

To double check our results, we follow Aitken and Harrison (1999), Javorcik (2004) and Haskel et al. (2007) and estimate the first-differencing model. As discussed in section III, It is an alternative method to the fixed effects model. The results of first-differencing model are presented in Table 7. While "the examination of longer differences gives relatively more weight to more persistent changes in the variables of interest and hence reduces the influences of noise" (Javorcik, 2004), the relatively short time period of our data set does not allow us to do so. In estimating the first differencing model, Javorcik (2004) and Haskel et al. (2007) keep the industry- and region-fixed effects. In our study, we estimated the first differencing model both with and without the industry- and region-fixed effects for comparison.

The results from the first differencing model without the industry- and region- fixed effects are presented in the upper panel of Table 7. It is clear that all horizontal linkage variables remain statistically insignificant after the differencing. All the positive vertical spillover effects remain statistically significant in all four different measures except in specification (3) where the forward linkage variable is marginal statistically insignificant. These results are quite consistent with those of the fixed effects model. This should not be a surprise. One main purpose of differencing is to remove fixed effects, hence one should expect the results to be similar to those of the fixed effects model.

However, the results from the first differencing model with the industry- and region-fixed effects are substantially different: while all the horizontal linkage variables remain insignificant, some vertical linkage variables become insignificant and bear an unexpected negative sign[viii]. This inconsistency may be partially due to multicollinearity.

After first differencing, the explanatory variables are correlated with the industry dummies. As a result, given the data set, we feel that the results from the fixed effects model and the first differencing model without the industry- and region-fixed effects are more reliable than those from the first-differencing model with industry- and region-fixed effects.

<Table 7 about here>

Another alternative to model the serial correlation and heteroskedasticity by robust standard errors, taking into account fixed effects, is to estimate the parameters of a population-averaged model. The results are presented in the lower panel of Table 7. Again the results are broadly in line with those of the fixed effects model and the first differencing model without the industry- and region-fixed effects.

## V. Conclusions

*Summary*

While important, the existing empirical results investigating productivity spillovers from FDI horizontal and vertical linkages simultaneously are not only relatively rare but also inconclusive. The current study follows a two-step procedure to investigate whether there are productivity spillovers from transactional linkages with MNEs in Chinese manufacturing. In the first step, TFP in firms is estimated using the Levinsohn-Petrin (2003) method. In the second step, the linkage effects of FDI on TFP are investigated. It is found that FDI generates positive vertical linkage effects in Chinese manufacturing at both the national and regional level, and limited positive horizontal spillovers at the regional level. The finding that horizontal spillovers are only local in scale is consistent with Wei and Liu (2006). When all existing firms in Chinese manufacturing are divided into four groups, OECD firms appear to gain from both vertical and probably horizontal linkages, and Hong Kong, Macao, and Taiwanese firms only benefit from backward linkage effects. In the domestic sector in which we are most interested, both SOEs and non-SOEs are hurt by competition from foreign firms in the same industries. While SOEs gain from vertical linkages with foreign firms, non-SOEs fail to do so.

The patterns of productivity spillovers from FDI in Chinese manufacturing seem to be determined by one key factor – technological capabilities of all firms involved, and this seems to be consistent with Cantwell (1989) who argues that the effectiveness of knowledge spillovers depends largely on the technical capabilities of the recipient firms. OECD firms gain from transactional linkages as they have the high technological capabilities. HMT firms are not hurt in competition in the same industries and benefit from vertical linage effects. The reason why SOEs perform better than non-SOEs may be that the former have higher capabilities due to their larger size (more resources) and long-term support by the Chinese government. Our findings also confirm that the linkage effects are to some extent sensitive to the measurement of foreign presence. In addition, the Chinese experience seems to resemble to some extent that in other emerging economies.

*Data Limitations*

The results from this study need to be interpreted with caution as there are several limitations. The most important issue is with the data set used. Although there are on average more than 20,000 observations each year in our sample, they come from 8 two-digit sectors and for a period of four years only. In addition, as the explanatory variables after first differencing are correlated with the industry dummies, our results from the fixed effects model are only qualitatively comparable with the first differencing model without the industry- and region-fixed effects and the population-average model, but not the first differencing model with industry- and region-fixed effects. A more comprehensive data set with a wider coverage of sectors and a longer time period may allow a researcher to capture the long term effects of FDI and obtain more robust results. Related to the first problem, the second caveat is that the relations among FDI, technological spillovers, and intra- and inter-industry linkages may be dynamic in nature and the effects are materialized with considerable time lags, but data limitations have forced us to analyze the question contemporaneously. Third, the input-output table produced in China is not sufficiently disaggregated. Thus, some horizontal linkages defined by this study could be vertical if a more disaggregated industrial classification is applied[ix]. Our fourth concern is related to the use of an input-output table as the proxy for FDI linkage effects in general. As the linkage behavior of multinational enterprises may well be different from that of local firms, the use of average industrial transaction coefficients for foreign firms may be problematic. Fifth, China had practiced local content requirement, tax holiday and duty rebate policies for MNEs. These policies may have affected the production and transaction behaviors of both MNEs and local Chinese firms, and hence our findings. However, we find it impossible to quantify the impact of these policies. Finally, in its early stage of opening to the outside world, China granted various fiscal and financial concessions or incentives in order to attract FDI. This led to round-tripping FDI, i.e. investment by Chinese residents made through intermediates in other countries that allow these investors to get any favorable treatment extended to foreign investors. The World Bank (2002) estimated that 20-30% of total FDI into China was the result of such 'round-tripping' from Hong Kong, Macao or Virgin Islands. One could argue that this kind of investment would be unlikely to generate any spillover benefits[x]. The extent of these policy measures was reduced after 1995 when China committed to national treatment of foreign firms (Wei, 2004) which implies that local Chinese firms hence have had less incentive to conduct this type of investment. Although our data period started from as late as 1998, it is still likely that some so-called Hong Kong, Macao, and Taiwanese firms included in the sample are actually round-tripped local Chinese firms. If these firms could be identified and excluded, the productivity spillover performance of HMT firms would probably be better.

Following Javorcik (2004), we call for further research using data that allow for identification of individual firms as actual transactional partners with MNEs rather than relying on input-output matrices to measure interactions between sectors. Furthermore, we suggest that econometric studies are complemented by case studies. Actually, Wei et al. (2008) find that almost all eight companies interviewed agree that local Chinese firms benefit from their horizontal and vertical linkages with foreign firms. Case studies can provide more insights on this topic.

*Policy Implications*

Given the tentative nature of the results obtained and the data limitations described above, we should exercise caution in drawing policy implications. Nevertheless, the scarcity of existing research on simultaneously investigating FDI horizontal and vertical linkage effects warrants some discussion of potential policy implications that could be derived from the above empirical findings. Recognizing the potential spillover effects of FDI linkages with the local economy, the Chinese governments, at the national and regional level, have devoted resources and launched policy initiatives to attract FDI and stimulate linkages between foreign and local firms. Our empirical results demonstrate the substantial impact that foreign firms have on a host country is through vertical linkages, hence providing some justification for some of those actions and policies. However, to benefit more from transactional linkages, firms themselves need to enhance their ability to learn. This is especially important for local firms in a developing country like China, as their technological capabilities are relatively low. High technological capabilities make it easier for local firms to forge vertical linkages with and learn from foreign firms in the related industries. High technological capabilities also enable local firms to be in a better position to compete and collaborate with foreign firms in the same industries, and could possibly turn the negative horizontal linkage effects around to be positive. The Chinese government needs to make every effort to provide a more favorable business environment to encourage local firms to conduct more R&D and improve their technological capabilities.

Secondly, as an important channel of spillovers is through labor mobility, establishing an efficient labor market is important for a local economy to benefit from the spillover effects of FDI. In China, despite the fact that labor migration (intra- and inter-region) has been a profound phenomenon, the *hukou* (household registration) system and regional disparity in the development of the labor market[xi] create a hindrance for local firms to benefit from the presence of MNEs. The government should adopt more proactive policies to deal with labor market inefficiencies.

Thirdly, the fact that horizontal productivity spillovers may be only local in scale is partially due to local protectionism (Batisse and Poncet, 2004) or regional disparity in China, or both. The barriers to flow of goods and services, to some extent, reduce horizontal linkages between regions (Wei and Liu, 2006). On the other hand, different development levels between coastal, inland and western areas may also hamper horizontal knowledge spillovers across regions. Thus, the Chinese government should remove these barriers and try to promote regional integration. Recent attempts at regional policies such as the *Develop the West* policy and the *Revitalize the North East* policy are moves in the right direction.

Fourthly, an important lesson that can be drawn relates to our finding that SOEs' performance is improved by the presence of foreign firms in related and supporting industries. To improve SOEs' efficiency, recently there have been many policy initiatives including addressing issues relating to technical change, subsiding innovations and technical change, reducing the gearing ratios by transforming debt into stocks, and promoting exports. The government has also tried to restructure industry via mergers, closures and bureaucratic restructuring. Some of the unprofitable SOEs have been merged with successful ones. Our finding suggests that policy analysis could also focus upon the economic significance of linkage effects from FDI.

Fifthly, China's economic reform has resulted in a substantial change in ownership structure. Industry is no longer dominated by SOEs. On the contrary, it is now dominated by non-state-owned Chinese enterprises and they have been the major source for employment creation and local economic development in addition to production. It is unlikely that this trend will be reversed. Hence, this imposes a requirement on government to help non-state-owned Chinese enterprises to benefit from FDI linkage effects. Policies in China by and large are still biased towards SOEs. However, we propose that these policies should be equally extended to non-SOEs.

Finally, home governments and managers of MNEs need to realize that MNEs can benefit from the presence of other firms in a host country. Thus, outward FDI can be encouraged.

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Appendix A. Data Sources and Variable Definitions

The firm level data set used in this study is from the *Annual Report of Industrial Enterprise Statistics* compiled by the State Statistical Bureau of China, covering firms during the period 1998-2001 in the following industries: Food processing, Food manufacturing, Beverage production, Garments and other fiber products, Medical and pharmaceutical products, Ordinary machinery manufacturing, Transport equipment manufacturing, Electrical machines and apparatuses, and Electronic and telecommunications equipment. For each industry, the Bureau collects detailed data on each industrial firm in operation. The data include information on ownership classification, value added[xii], output, capital stock, number of employees, sales, intangible assets, new product sales and exports. To remove the influence of inflation, variables have been adjusted by relevant deflators. Price indices for total manufacturing fixed assets and industrial output are used, which are obtained from the *China Statistical Yearbook* 2002.

| year | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|
| Total | 23,355 | 26,540 | 24,695 | 19,597 |
| No. of Domestically-owned Firms | 14,966 | 16,568 | 14,180 | 10,377 |
| No. of Foreign Firms | 8,389 | 9,972 | 10,515 | 9,220 |
| *Of which* | | | | |
| No. of Firms with FDI by HMT only | 4,448 | 5,341 | 5,540 | 4,739 |
| No. of Firms with FDI by OECD only | 3,786 | 4,469 | 4,793 | 4,304 |
| No. of Firms with FDI by HMT and OECD | 155 | 162 | 182 | 177 |

Due to entry and exit and ownership restructuring, the number of firms in operation is changing over time. In this study, the same firms can be identified based on their identifiers. The data are cleaned via extensive checks for nonsense observations, outliers, coding mistakes, and the like. This finally produces an unbalanced set of 32,008 firms. The detailed distribution by year and by ownership is provided in the table above. A firm is defined to be domestically-owned, if its foreign equity participation, if any, is below 25%. In this data set, there are two types of foreign presence: overseas Chinese from Hong Kong, Macao and Taiwan (HMT), and other foreign investors mainly from OECD countries (OECD).

In the paper, region is defined at the level of province, autonomous region and central municipality. Mainland China can be broadly divided into three macro areas and 31 provinces, autonomous regions and central municipalities. The coastal area includes Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Guangxi and Hainan. The central area includes Shanxi, Inner Mongolia, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei and Hunan. And the western area includes Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang and Tibet. There are no data available for Tibet. Chongqing was not separated from Sichuan until 1996 and thus been treated as one combined province. Hence in total, there are 29 regions included in our sample.

The I-O table uses an industry classification different from the SIC classification of the database of *Annual Report of Industrial Enterprise Statistics*. Nonetheless the I-O table provides the correspondence with the SIC classification at a 3-digit level. We aggregate the 59 3-digit industries to 25 sectors in the I-O tables (see Table A1).

Table A1. Classification Scheme

| Industry | SIC Code (China) | I-O Sector |
| --- | --- | --- |
| **Food processing; Food manufacturing** | **13; 14** | |
| Food and feed; Vegetable oil | 131; 132 | 14 |
| Sugar | 133 | 15 |
| Slaughtering, meat products and egg products | 134 | 16 |
| Aquatic products | 135 | 17 |
| Salt; Other food processing; Pastry and confectionery manufacturing; Dairy products; Canned food; Fermented products; Spices; Other food manufacturing | 136; 139; 141; 142; 143; 144; 145; 149 | 18 |
| **Beverage production** | **15** | |
| Alcohol and wine | 151 | 19 |
| Soft drinks; Tea; Other beverages | 152; 155; 159 | 20 |
| **Garments and other fiber products** | **18** | |
| Apparel; Hats; Shoes; Other apparel | 181; 182; 183; 189 | 28 |

*Table A1 continued*

| Industry | SIC Code (China) | I-O Sector |
|---|---|---|
| **Medical and pharmaceutical products** | **27** | |
| Medicines and chemical reagents; Pharmaceutical preparations; Chinese medicines; Veterinary medicines; Biological products | 271; 272; 273; 274; 275 | 44 |
| **Ordinary machinery manufacturing** | **35** | |
| Boiler And Power Generation equipment | 351 | 62 |
| Metal Processing machinery | 352 | 63 |
| General equipment; Bearings and Valves; General parts; Castings and Forgings; General machinery repair; Other general machinery | 353; 354; 356; 357; 358; 359 | 64 |
| **Transport equipment manufacturing** | **37** | |
| Railway transport equipment | 371 | 67 |
| Vehicles | 372 | 68 |
| Motorcycles; Tram; Transport equipment repair; Other transport equipment; | 373; 375; 378; 379 | 72 |
| Bicycles | 374 | 71 |
| Shipping | 376 | 69 |
| Aircraft and spacecraft | 377 | 70 |
| **Electrical machines and apparatuses** | **40** | |
| Motors | 401 | 73 |
| Electricity transmission, distribution & control equipment; Electrical engineering equipment; Lighting equipment; Electrical equipment repair; Other electrical machinery | 402; 404; 407; 408; 409 | 75 |
| Household electrical appliances | 406 | 74 |
| **Electronic and telecommunications equipment** | **41** | |
| Communication equipment; Radar; Broadcast and television equipment; Electronic and telecommunications equipment repair; Electronic equipment | 411; 412; 413; 418; 419 | 79 |
| Computers | 414 | 76 |
| Electronic devices; Electronic components | 415; 416 | 78 |
| Household electronic appliances | 417 | 77 |

Appendix B. Levinsohn-Petrin Estimation Procedure

Although a full description of Levinsohn-Petrin estimation is beyond the scope of this paper (interested readers are referred to Levinsohn and Petrin (2003)), a brief sketch of the procedure is provided below.

The estimation method starts with the following production function[xiii]:

$y_t = c_0 + c_1k_t + c_2l_t$ (1)

where $y_t$ is the logarithm of the value added, $k_t$ and $l_t$ are the logarithms of capital and labor respectively. Following Levinsohn and Petrin (2003) one can re-write (1) in the following way

$y_t = c_0 + c_1l_t + c_2k_t + c_3m_t + \omega_t + \eta_t$ (2)

where $\eta_t$ is the i.i.d. component of the disturbance term, and $\omega_t$ is the state dependent unobserved productivity. Labor is assumed to be a variable input, while capital is a state variable. Demand for the intermediate inputs is assumed to be a function of capital and the state dependent productivity term: $m_t = m_t(k_t; \omega_t)$. When this demand function is monotonically increasing in $\omega_t$, one can express $\omega_t$ by inverting the intermediate inputs demand function. In this case, the unobservable productivity is expressed in terms of observable variables. A final assumption required for the identification of the parameters of the production function is that $\omega_t$ follows a first order Markov process: $\omega_t = E(\omega_t|\omega_{t-1}) + \xi_t$, where $\xi_t$ is an innovation to productivity that is uncorrelated with $k_t$ (Levinsohn and Petrin, 2003). With this model in hand, one can consistently estimate the parameters of the production function.

Table 1. The Share of Foreign Firms in Chinese Manufacturing, 2001

%

| *Industry* | *Fixed Assets* | *Employment* | *Industrial Output* |
|---|---|---|---|
| Food processing | 23 | 18 | 24 |
| Food manufacturing | 42 | 25 | 40 |
| Beverage production | 35 | 17 | 30 |
| Garments and other fiber products | 45 | 47 | 46 |
| Medical and pharmaceutical products | 21 | 12 | 22 |
| Ordinary machinery manufacturing | 23 | 10 | 22 |
| Transport equipment manufacturing | 30 | 11 | 31 |
| Electrical machines and apparatuses | 38 | 28 | 33 |
| Electronic and telecommunications equipment | 66 | 55 | 74 |

Source: China Statistical Yearbook.

Table 2. Descriptive Statistics

| | | *Variable* | *Mean* | *s.d.* | *min* | *max* | *Number of Observations* |
|---|---|---|---|---|---|---|---|
| | | log(value added) | 8.140 | 1.964 | 0.000 | 16.398 | 96,255 |
| | | log(capital) | 8.687 | 1.891 | -0.004 | 16.155 | 100,595 |
| | | log(labor) | 5.092 | 1.332 | 0.000 | 11.579 | 102,157 |
| | | log(material) | 9.170 | 1.978 | 0.000 | 17.192 | 101,425 |
| | | log(TFP) | 4.582 | 1.908 | -5.481 | 12.274 | 94,730 |
| Measure of FDI spillover effects | Horizontal variable | Capital | 0.427 | 0.160 | 0.005 | 0.761 | 102,236 |
| | | Employment | 0.348 | 0.246 | 0.001 | 0.869 | 102,236 |
| | | Capital weighted by sales | 0.402 | 0.176 | 0.009 | 0.835 | 102,236 |
| | | Capital weighted by employment | 0.260 | 0.194 | 0.003 | 0.755 | 102,236 |
| | Backward variable | Capital | 0.094 | 0.145 | 0.000 | 0.645 | 102,236 |
| | | Employment | 0.083 | 0.150 | 0.000 | 0.748 | 102,236 |
| | | Capital weighted by sales | 0.092 | 0.153 | 0.000 | 0.730 | 102,236 |
| | | Capital weighted by employment | 0.067 | 0.130 | 0.000 | 0.662 | 102,236 |
| | Forward variable | Capital | 0.040 | 0.052 | 0.001 | 0.310 | 102,236 |
| | | Employment | 0.031 | 0.050 | 0.001 | 0.345 | 102,236 |
| | | Capital weighted by sales | 0.039 | 0.054 | 0.001 | 0.340 | 102,236 |
| | | Capital weighted by employment | 0.024 | 0.042 | 0.001 | 0.289 | 102,236 |

Notes: s.d. = standard deviation; min = minimum; max = maximum

Table 3. OLS, Fixed Effects and Levinsohn-Petrin Estimation for Chinese Industry

| | *OLS* | *Fixed Effects* | *Levinsohn-Petrin* |
|---|---|---|---|
| **Food processing; Food manufacturing** | | | |
| *log(capital)* | 0.260** | 0.029** | 0.137** |
| | (0.008) | (0.010) | (0.013) |
| *log(labor)* | 0.797** | 0.425** | 0.445** |
| | (0.011) | (0.022) | (0.013) |
| *Number of Observations* | 27,393 | 27,393 | 27,200 |
| **Beverage production** | | | |
| *log(capital)* | 0.292** | 0.057** | 0.137** |
| | (0.014) | (0.016) | (0.020) |
| *log(labor)* | 0.970** | 0.426** | 0.572** |
| | (0.020) | (0.048) | (0.034) |
| *Number of Observations* | 6,484 | 6,484 | 6,434 |
| **Garments and other fibre products** | | | |
| *log(capital)* | 0.195** | 0.100** | 0.148** |
| | (0.009) | (0.016) | (0.024) |
| *log(labor)* | 0.657** | 0.429** | 0.347** |
| | (0.015) | (0.028) | (0.019) |
| *Number of Observations* | 11,523 | 11,523 | 11,502 |
| **Medical and pharmaceutical products** | | | |
| *log(capital)* | 0.301** | 0.059** | 0.194** |
| | (0.014) | (0.018) | (0.022) |
| *log(labor)* | 0.764** | 0.327** | 0.461** |
| | (0.021) | (0.054) | (0.036) |
| *Number of Observations* | 6,399 | 6,399 | 6,373 |
| **Ordinary machinery manufacturing** | | | |
| *log(capital)* | 0.255** | 0.036** | 0.183** |
| | (0.010) | (0.012) | (0.019) |
| *log(labor)* | 0.617** | 0.289** | 0.474** |
| | (0.014) | (0.033) | (0.022) |
| *Number of Observations* | 11,970 | 11,970 | 11,883 |
| **Transport equipment manufacturing** | | | |
| *log(capital)* | 0.342** | 0.066** | 0.157** |
| | (0.011) | (0.015) | (0.025) |
| *log(labor)* | 0.669** | 0.402** | 0.428** |
| | (0.015) | (0.036) | (0.029) |
| *Number of Observations* | 10,853 | 10,853 | 10,775 |
| **Electrical machines and apparatuses** | | | |
| *log(capital)* | 0.295** | 0.080** | 0.183** |
| | (0.010) | (0.015) | (0.030) |
| *log(labor)* | 0.626** | 0.544** | 0.369** |
| | (0.015) | (0.032) | (0.022) |
| *Number of Observations* | 10,277 | 10,277 | 10,238 |
| **Electronic and telecommunications equipment** | | | |
| *log(capital)* | 0.300** | 0.066** | 0.195** |
| | (0.011) | (0.019) | (0.029) |
| *log(labor)* | 0.631** | 0.543** | 0.331** |
| | (0.016) | (0.033) | (0.020) |
| *Number of Observations* | 9,831 | 9,831 | 9,782 |

Notes: Standard errors are reported in parentheses. ** denotes significance at 1% level.

Table 4: Linkage Effects of FDI on Productivity at the National Level

| Measure of FDI spillover effects | Capital | Employment | Capital weighted by sales | capital weighted by employment |
|---|---|---|---|---|
| Horizontal | 0.083 | -0.298 | -0.145 | -0.107 |
| | (0.400) | (0.398) | (0.544) | (0.351) |
| Backward | 1.587** | 1.099** | 1.169** | 1.093** |
| | (0.514) | (0.341) | (0.388) | (0.334) |
| Forward | 1.592* | 1.773** | 1.190** | 2.109* |
| | (0.628) | (0.562) | (0.434) | (0.833) |
| Firm dummies | Yes | Yes | Yes | Yes |
| Year dummies | Yes | Yes | Yes | Yes |
| Industry dummies | Yes | Yes | Yes | Yes |
| Region dummies | Yes | Yes | Yes | Yes |
| Model Goodness-of-fit Test | $5.73 \times 10^{9}$** | $1.98 \times 10^{9}$** | 5.91** | 5.62** |
| Number of observations | 94,730 | 94,730 | 94,730 | 94,730 |

Notes:
1. The error terms are corrected for clustering at industry-year level.
2. Robust standard errors are in parentheses.
3. † significant at 10%; * significant at 5%; ** significant at 1%.

Table 5 Linkage Effects of FDI on Productivity at the Regional Level

| Measure of FDI spillover effects | Capital | Employment | Capital weighted by sales | capital weighted by employment |
|---|---|---|---|---|
| Horizontal_within_region | 0.065 | 0.115 | 0.106 | 0.212* |
| | (0.050) | (0.072) | (0.069) | (0.090) |
| Backward_within_region | 0.366† | 0.140 | 0.488 | 0.846† |
| | (0.187) | (0.285) | (0.306) | (0.471) |
| Forward_within_region | 2.022** | 1.631† | 1.134 | 2.067* |
| | (0.732) | (0.909) | (0.771) | (0.963) |
| Horizontal | 0.054 | -0.434 | -0.264 | -0.335 |
| | (0.333) | (0.345) | (0.450) | (0.309) |
| Backward | 1.583** | 1.204** | 0.960* | 0.709† |
| | (0.459) | (0.362) | (0.386) | (0.424) |
| Forward | 1.250** | 1.292** | 1.146** | 1.371* |
| | (0.438) | (0.371) | (0.285) | (0.664) |
| Firm dummies | Yes | Yes | Yes | Yes |
| Year dummies | Yes | Yes | Yes | Yes |
| Industry dummies | Yes | Yes | Yes | Yes |
| Region dummies | Yes | Yes | Yes | Yes |
| Model Goodness-of-fit Test | $1.03 \times 10^{9}$** | 79.98** | 93.94** | 7.67** |
| Number of observations | 94,730 | 94,730 | 94,730 | 94,730 |

Notes:
1. The error terms are corrected for clustering at industry-year level.
2. Robust standard errors are in parentheses.
3. † significant at 10%; * significant at 5%; ** significant at 1%.

Table 6 Linkage Effects on Firms of Different Ownership Groups

| | Hong Kong, Macao and Taiwan Firms | | | | OECD Firms | | | |
|---|---|---|---|---|---|---|---|---|
| Measure of FDI spillover effects | Capital | Employment | Capital weighted by sales | Capital weighted by employment | Capital | Employment | Capital weighted by sales | Capital weighted by employment |
| Horizontal | -0.310 | -0.167 | 0.217 | 0.178 | 0.493† | 0.224 | 0.989* | 0.198 |
| | (0.320) | (0.347) | (0.317) | (0.333) | (0.255) | (0.281) | (0.391) | (0.284) |
| Backward | 0.724* | 0.425 | 0.441† | 0.244 | 2.343** | 1.438** | 1.453** | 1.447** |
| | (0.317) | (0.281) | (0.224) | (0.253) | (0.438) | (0.381) | (0.378) | (0.406) |
| Forward | 0.843 | -0.502 | 0.302 | -0.945 | 1.318* | 1.345* | 0.715 | 1.559* |
| | (0.582) | (0.681) | (0.738) | (0.786) | (0.617) | (0.593) | (0.442) | (0.772) |
| Firm dummies | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year dummies | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Industry dummies | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Region dummies | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Model Goodness-of-fit Test | 7.73** | 6.89** | 5.66** | 6.19** | 24.55** | 28.32** | 28.39** | 83.36** |
| Number of observations | 20,083 | 20,083 | 20,083 | 20,083 | 17,379 | 17,379 | 17,379 | 17,379 |
| | SOEs | | | | Non-SOEs | | | |
| Measure of FDI spillover effects | Capital | Employment | Capital weighted by sales | Capital weighted by employment | Capital | Employment | Capital weighted by sales | Capital weighted by employment |
| Horizontal | 0.079 | -0.733† | -0.586 | -0.690† | 0.107 | -1.001* | -0.484 | -0.992* |
| | (0.357) | (0.398) | (0.483) | (0.347) | (0.220) | (0.467) | (0.567) | (0.452) |
| Backward | 1.369* | 0.956† | 1.086* | 1.199* | 0.021 | 0.526 | 0.171 | 0.604 |
| | (0.668) | (0.515) | (0.492) | (0.478) | (0.541) | (0.457) | (0.439) | (0.498) |
| Forward | 2.467* | 4.007** | 1.943* | 5.416** | 0.566 | -0.090 | 0.024 | 0.394 |
| | 1.025) | (0.892) | (0.843) | (0.938) | (1.169) | (1.065) | (1.091) | (1.197) |
| Firm dummies | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year dummies | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Industry dummies | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Region dummies | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Model Goodness-of-fit test | 8.44** | 2543.35** | $1.90 \times 10^{11}$** | 9.17 ** | 23.45** | 31.77** | 31.78 ** | 33.30** |
| Number of observations | 49,808 | 49,808 | 49,808 | 49,808 | 6,784 | 6,784 | 6,784 | 6,784 |

Notes: 1. The error terms are corrected for clustering at industry-year level. 2. Robust standard errors are in parentheses. 3. † significant at 10%; * significant at 5%; ** significant at 1%.

Table 7: Linkage Effects of FDI on Productivity, Alternative Estimations

| ***First Differencing Model*** | *(1)* | *(2)* | *(3)* | *(4)* |
|---|---|---|---|---|
| Measure of FDI spillover effects | Capital | Employment | Capital weighted by sales | capital weighted by employment |
| Horizontal | -0.016 | -0.312 | -0.208 | -0.141 |
| | (0.351) | (0.328) | (0.461) | (0.321) |
| Backward | 0.886* | 0.759** | 0.768* | 0.784** |
| | (0.347) | (0.226) | (0.334) | (0.262) |
| Forward | 0.878† | 1.347† | 0.591 | 1.681† |
| | (0.473) | (0.783) | (0.383) | (0.988) |
| Year dummies | Yes | Yes | Yes | Yes |
| Industry dummies | No | No | No | No |
| Region dummies | No | No | No | No |
| Model Goodness-of-fit test | 9.01** | 3.35** | 7.30** | 2.62** |
| Number of observations | 61099 | 61099 | 61099 | 61099 |
| ***Population-Averaged Model*** | *(1)* | *(2)* | *(3)* | *(4)* |
| Measure of FDI spillover effects | Capital | Employment | Capital weighted by sales | capital weighted by employment |
| Horizontal | 0.030 | -0.287† | -0.159 | -0.129 |
| | (0.097) | (0.151) | (0.155) | (0.156) |
| Backward | 1.148** | 0.897** | 0.940** | 0.918** |
| | (0.334) | (0.205) | (0.237) | (0.211) |
| Forward | 1.168** | 1.526** | 0.862** | 1.869** |
| | (0.398) | (0.454) | (0.338) | (0.542) |
| Year dummies | Yes | Yes | Yes | Yes |
| Industry dummies | No | No | No | No |
| Region dummies | No | No | No | No |
| Model Goodness-of-fit Test | 69.18** | 75.65** | 70.40** | 75.55** |
| Number of observations | 61,099 | 61,099 | 61,099 | 61,099 |

Notes: 1. The error terms in first-differencing model are corrected for clustering at industry-year level. 2. Robust standard errors are in parentheses. 3. † significant at 10%; * significant at 5%; ** significant at 1%.

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[i] According to the OECD (1996), food, drink, and garments belong to low-tech industries, and electrical machines and apparatuses and electronic and telecommunications equipment are medium-tech industries, while high-tech industries include medical and pharmaceutical products, ordinary machinery manufacturing, and transport equipment manufacturing.

[ii] Due to space constraints, standard deviations for between and within components are not reported, but are available upon request.

[iii] Due to space constraints, the correlation coefficient matrix for spillovers variables is not presented but is available upon request.

[iv] Translog production functions were also estimated industry by industry, but the results are unsatisfactory. This is largely because of the multicollinearity problem. The high correlations between the linear and the quadratic and cross terms in the translog specification may render inefficient estimations.

[v] Please see Appendix A for the definitions of regions.

[vi] We should note here that productivity of foreign firms may also be influenced by factors outside China. We thank an anonymous referee for this point.

[vii] Blalock and Gertler (2007) only focus on horizontal and backward linkages, not forward linkages.

[viii] The detailed results from the first differencing model with the industry- and region-fixed effects are not presented because of space limitations, but available upon request.

[ix] This may partially explain why our findings on horizontal spillovers are different from Wei and Liu (2006). Because we have to follow the definition of the industries used by the I-O table, our industries are more broadly defined than those in Wei and Liu (2006). Hence our results are not comparable.

[x] We thank an anonymous referee for this comment.

[xi] The coastal area has a better developed labor market than the inland.

[xii] Value added here is defined as "the difference between the selling price of a product and the cost of externally purchased materials and services".

[xiii] It should be acknowledged that a production function like this is parsimonious, imposing a strong assumption of linear additivity of materials (raw materials and energy). Unfortunately, data on materials are not available, therefore, the obtained empirical results should be interpreted with caution.